SECTION FRANCAISE
de la
"HEALTH PHYSICS SOCIETY"



INTERNATIONAL CONFERENCE
on
RADIOACTIVE POLLUTION OF GASEOUS MEDIA
Saclay November 12-16, 1963

# AIR AND GAS CLEANING METHODS FOR REACTOR CONTAINMENT VESSELS

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## I - INTRODUCTION -

In this paper, a survey is made of the existing and some proposed new methods for the control and purification of air and gases which might be released from a reactor contained or confined for protection of the health and safety of the public from potential accidents. The difference between confinement and containment concepts must be considered. The problems involved and the need for decontamination, site selection, exclusion area, population density, distance, etc., have been discussed elsewhere. For example, in the recent IAEA (1963) proceedings series (Bombay, India) March 11-15, 1963 "Siting of Reactors and Nuclear Research Centers," IAEA Vienna STI/Pub/72. We propose to discuss here the safety measures necessary to control the release of radioactive materials to the environment. This requires special systems which must function effectively to minimize loss of fission products such as halogens and particulates. These can penetrate the confinement filters or the containment vessel to a limited extent even after cleaning.

## DISCLAIMER

## II. CONTAINMENT VERSUS CONFINEMENT CONCEPTS - THEIR EFFECT UPON THE CONTROL OF ACCIDENTAL RELEASES FROM REACTORS.

Before discussing the principles of behavior of radioactive contaminants within reactor containment vessels, related buildings or released fission product or control systems, it is necessary to emphasize the basic differences in control concepts between containment and confinement systems.

The fundamental differences to be considered from a cleaning or contaminant removal standpoint are beyond the concepts of stored energy and closed environments at elevated pressure.

Confinement is the older technique used in practice since it was first installed on the Oak Ridge X-10, 3 MW graphite moderated air cooled pile in 1948. This was done in order to prevent further local deposition of radioactive releases from fuel element ruptures. No exhaust filters were provided prior to 1948 and only a tall stack (200 feet) provided control of activated gas and particles by dispersion to the atmosphere. It should be recognized that in confinement systems, the installed air or gas cleaning devices, such as scrubbers or filters, are continuously on-stream and are functioning at all times handling routine releases such as building ventilation air with minimal contamination. When they are called upon to handle serious accident situations, such as the installed stack filters were required to do at Windscale, they were already functioning and required no actuating signal or trigger to respond. The duct work and stack also behaved as settling chambers for retention of coarse particles and caused some agglomeration of finer particles. These particles also became condensation surfaces and adsorbed significant quantities of iodine and other volatile radionuclides. Until a later decision was made during the accident to add water to the burning pile, these were the major factors responsible for reduction of stack releases. A fog spray or dousing system reduces the consequences of the accidental releases associated with melting of the reactor fuel or similar sources of contamination. In confinement systems, the installed cleanup units can handle both routine releases and minor accidents as well as major accidents. In the case of routine operations, access to the cleanup system may be made for maintenance and renewal of scrubbing solutions or filters. This may be required at frequent intervals. In the case of the severe accident or MCA (maximum credible accident), the filter house or scrubber may become so seriously contaminated with radioactive long-life fission products that it may be abandoned and buried. If the reactor is intended to be continued in service, an alternate unit must be available or a new cleanup facility must be constructed. It should also be noted that the confinement system must be protected from the effects of the release of large quantities of steam, hot gases and decay heat from collected fission products. This feature may or may not be necessary in containment systems depending upon when the cleanup systems are activated. If they are initiated at the same time that the fog spray or containment pressure reduction sprays are actuated, they must have the same capabilities. In addition, they must also have the ability to function under saturated conditions of increased or changing atmospheric pressures due to the stored energy released within the containment. The effect of the spray system in reducing containment pressures will, of course, produce a changing atmospheric pressure situation within the containment vessel.

If it can be safely assumed that the steam environment and its effects will be essentially eliminated by a long delay in time before core-melting takes place and that a simultaneous release of fission products with the steam could not occur, then the activation of the cleanup system could be delayed until optimum gas cleaning or filter operating conditions prevailed. Unfortunately at the present time we do not have enough assurance based on experimental studies and accident experience to make such a safety judgment. In view of this situation, the conservative approach must involve the selection of containment and confinement cleanup systems that will function under the worst anticipated conditions.

With such objectives in mind, it can be stated that confinement systems are more flexible in that they can utilize maximum air flow as a means of control for routine and minor accidental releases and can utilize reduced flows in major releases to obtain better decontamination. Filters and other gas cleaning devices would often function better on small particles at reduced air flow. They do have the disadvantage, however, that the cleaning device performance specification must be higher because one pass continuous flow through a duct system will not provide the optimum retention time for absorption, adsorption and agglomeration. These can all be useful mechanisms in a closed recirculating system such as an emergency cleanup unit installed within or outside a containment system but subject to the same environments produced within the containment vessel.

Containment cleanup systems have the advantage that they have available sufficient residence time for the released contaminants to agglomerate by Brownian diffusion or particles can grow by condensation mechanisms from the saturated environment in the case of water reactors. Adsorption can take place on particle surfaces on the containment walls in relatively undisturbed conditions (in stagnant air films). Further advantages exist because the fixed volume provides sufficient time for settling and deposition of particles. The containment spray system can work more effectively on particle removal because it provides a multiple pass system as contrasted to a scrubber on a process waste stream or in a confinement cleaner. The use of internal cleanup devices is enhanced because of the recirculation aspect since several passes can be made through a single device such as a scrubber or filter hence the initial efficiency need not be as high to obtain a given final performance.

It is apparent from the above discussion that confinement and containment systems each have their own characteristics and merits for prevention of radioactive releases under routine and accidental conditions. For the routine case, the confinement system is operating as designed. No special benefit in this case accrues to containment; as a matter of fact, small releases within the containment vessel may cause an exposure to occupants in research or testing reactors. The handling of routine releases in contained reactors is also done in most cases with either continuous or batch cleanup systems using decay or detention tanks or lines. The choice of containment versus confinement involves economics as well as safety, but either system can be made to function as intended to protect the environment and the public residing near the reactor facility in the event of a serious malfunction or accident.

## III. - CONFINEMENT AND CONTAINMENT METHODS -

The following confinement and containment methods have been developed or are in use in the United States.

A) Confinement
B) Containment
C) Containment plus confinement
D) Containment plus pressure suppression
E) Containment with valving
F) Double containment
G) Diffusion board confinement

### A) CONFINEMENT

The reactor building is confined by a nearly impervious envelope including masonry or metal walls (Figure 1). In-leakage of small volumes of air is not serious as it is part of the usual building ventilation system.

Inside the building a negative pressure of 1 inch of water is maintained and the static pressure building load does not exceed 1½ to 2 psi. The air exhausted passes through filters or scrubbers and adsorbers and is then released to a tall stack. Experiment has shown that if a scrubber is used it must be followed by a filtration system. In most cases the inlet and exhaust air are prefiltered. In case of an accident, since the building leaks inward, all fission products released pass to the filters and vent the limited stored energy. Fog sprays are needed to lower the temperature, condense the steam formed or to quench the burning fuel slugs.

### B) CONTAINMENT

Figure 2 shows what is commonly described as "Containment." Reactors used in the United States power reactor program are essentially water cooled nuclear power plants with significant amounts of stored energy. Containment is designed to confine all energy release plus the contaminants. Valves which can be rapidly closed take care of releases to the stack during routine operation. The containment vessel is made of steel or of reinforced concrete with a steel membrane. The static pressure is equal to accident design energy release conditions. For most cases, we consider a permissible dynamic leakage equal to 0.1% of the contained weight (or volume) of air per 24 hours at design pressure. Sprays are used to lower pressure. Optional control systems can include recirculating air cleaning systems, a foam generator or both. Under accident conditions, the isolation valves which are used to confine the contaminants released must close within a short interval. They may be installed in tandem to provide redundancy for safety. Boiling water and pressurized water reactors have been contained by the unfired pressure vessels. A few others such as advanced gas cooled (EGCR) and organic moderated (Piqua) have also been contained with different stored energy considerations.

C) CONTAINMENT PLUS CONFINEMENT

In the containment plus confinement method, two complete barriers surround the primary system (Figure 3). The outer confinement vessel can be metal plus concrete or only a shell of reinforced concrete whose strength is provided by the needed shielding thickness. A negative pressure of up to 6" $H_2O$ may be maintained inside the annular section between the vessels. The containment vessel is made of steel and reinforced concrete. If an accident occurs the contaminants leaking from the containment vessel are absorbed and filtered in the confinement system before their release through the stack.

The retentive capability of the primary containment is identical to that of the system described above.

D) CONTAINMENT PLUS PRESSURE SUPPRESSION

Pressure suppression plus containment method is suitable for application to either type of water reactor. It has only been applied recently to large boiling water reactors of the direct cycle type (Figure 4). The primary system is contained within a dry well containment shell and the primary steam is piped to the turbine through double valves plus the turbine stop valve. The dry well is actually a small containment vessel designed for the maximum credible accident release of internal energy. The dry well vents the steam (stored energy) from an internal pipe break through jet condenser nozzles placed in a quench tank located in a vapor tight suppression chamber or pool containing a large water volume. The air and non-condensable gases pass through the water and are trapped above the pool while the steam and some fission products are trapped. The refueling building is used for refueling accident release control. It is built over the reactor plant and provides confinement during refueling. It has a scrubber or a filter adsorber cleanup system and functions in a similar manner. The routine gases are ejected and released to a tall stack. The same stack also functions as a dilution device for the releases from the refueling building confinement scheme. The volumes released are minimal to reduce size of scrubber or filter units. A high efficiency is thus obtained for the retention of contaminants.

E) CONTAINMENT WITH VALVING

Figure 5 shows the method of containment with valving. It has been applied recently to the New Production Reactor at Hanford. This system is similar to the total containment method. A series of valves are located in the roof structure of the building to release stored energy from a pressurized water reactor piping break. The stored energy of the steam release is thus vented in the case of an accident before the fuel melts. The valves are "butterfly type" and are normally open. The covers located above them are shut during reactor operation. When the pressure builds up the closed covers "pop open" at a predetermined pressure. The "butterfly" valves close after the stored energy is released. After the steam release, a clean-up system with high efficiency filters and adsorbers becomes operative. The system can be considered as an alternate to pressure suppression which enables stored energy to be condensed.

F) DOUBLE CONTAINMENT

The double containment concept is planned for the Malibu Beach reactor (City of Los Angeles) (Figure 6). A license has been recently requested for the construction of this reactor. Each barrier used is similar to single containment, but the two concentricly located containment vessels are spaced a few feet apart. The annular space between the vessels is bound by the two steel membranes and is to be filled with a load bearing porous media denoted as "Popcorn Concrete". This porous volume is continuously pumped at a negative controlled pressure with respect to the ambient atmosphere. The leakage of each membrane is 0.1% per day and with two in series, hence less than 0.01% would be expected as an overall figure if the two were pressurized without continuous pumping. According to the designers, no contamination can be released if the pumping is maintained throughout the accident. It is necessary to admit at present that this is a theoretical, or at least hypothetical, condition since it has not been tested on a large scale. Some degree of contamination could be released before the routine release isolation valves go into operation under the conditions corresponding to an accident. With a pump failure, a positive pressure also results. The system is designed to condense the released steam and to provide control comparable to single containment within the inner vessel. The cost for the construction of this double containment may be high in capital expenditure although the major cost is expected to be necessary for shielding concrete rather than the containment structures.

G) DIFFUSION BOARD CONFINEMENT

The technique of diffusion board confinement (Figure 7) was developed at Harvard as a new approach. It is based on a controlled filtered release of stored energy. All but the noble gases are decontaminated by the diffusion membrane and the steam is released to the atmosphere without a serious, prolonged pressure rise. The released steam passes through carefully designed and tested diffusion membranes which are porous to gases and steam. In the event that it may be needed, a containment system for noble gases is shown in dotted lines. This development was intended to reduce the cost of building confinement or safety systems. Confinement or containment may involve 8 to 15% of the cost of an overall plant. The diffusion boards developed to date (Figure 8) are formed of various laminated components in series such as filter media - honeycomb - filter media. The honeycomb section is made of expanded aluminum and then filled with activated carbon or silver plated silica gel having a high adsorptive capacity for iodine, 99.9%. The airborne particles are retained on glass fiber media at comparable efficiency. Ceramic diffusion panels developed to date are composed of glass fibers and ceramic bonding materials capable of withstanding very high temperatures. Small panels have been used in the experiments presently in progress to evaluate efficiency, pressure drop and resistance to shock and steam. Table 1 shows the particle removal results obtained with 0.08μ uranine. In each case, it has been possible to attain efficiencies higher than 99.9%.

The results of the adsorption of iodine by composite Harvard diffusion panels are also given in Table 2. At the present time, the ceramic boards are being evaluated. High particle removal has been obtained. However, it has only been possible to retain < 97% of the iodine without further treatment of the ceramic fiber. Further studies will be undertaken to attain the wanted decontamination factors of 99.9% for halogen removal.

## IV. CONFINEMENT VERSUS CONTAINMENT FILTER REQUIREMENTS

In this section, a brief survey of confinement versus containment filter requirements is presented. Table 3 summarizes each of the above concepts with their basic requirements. Some examples of each type are given. Table 4 compares the requirements. These two tables are self-explanatory and there is no need to elucidate further on these points.

High decontamination efficiency (99.9%) is necessary in the confinement systems since only a single pass is obtained through the filter.

The concentration of contaminants remaining after a recirculating filtration operation in a containment vessel is given by the equation:

$$C = Co\,e^{-\frac{nQ}{V}t}$$

where $n$ = efficiency
$Co$ = initial concentration
$V$ = contained volume
$Q$ = air flow (C.F.M.)
$t$ = time of recirculation

In the containment methods it is thus seen that the initial filter efficiency is not so critical. An efficiency of 95 - 99% is adequate in most instances since it will increase with each pass of the filtered gas.

In the containment systems the filters must resist steam temperature and shock waves which are more important than in the confinement systems. The capacity of the filter system can be much lower because of recirculation. In both, decontamination occurs because of plateout, adsorption, settling and spray collection.

## V. - CONCLUSION -

It is necessary to consider the economical point of view presented by the confinement and containment methods. This requires consideration in detail in estimating the construction and operational cost of various systems according to their complexity. Both confinement and containment concepts can be quite sophisticated in implementation. Because stored energy can be dispersed readily in confinement systems, confinement systems may be lower in initial capital cost but much higher in operating costs than containment construction because large air volumes are continuously filtered.

TABLE 2

EFFICIENCY OF HARVARD DIFFUSION BOARD FOR IODINE VAPOR REMOVAL*
(All one half-inch boards)

| Size and** Adsorbent | ½" Empty, 1106-B Both Sides (3 Tests) | ½" Activated Charcoal 1106-B Both Sides (3 Tests) | ½" Silvered Silica Gel 1106-B Both Sides (2 Tests) | ½" Activated Charcoal, FG-50** Upstream, 1106-B Downstream (3 Tests) |
|---|---|---|---|---|
| Upstream Conc. ppm | 5.69 | 5.49 | 5.40 | 6.14 |
| Upstream conc. mg/l | 0.0659 | 0.059 | 0.056 | 0.0636 |
| Downstream conc. mg/l | 0.0463 | $1.026 \times 10^{-4}$ | $1.023 \times 10^{-4}$ | $33.7 \times 10^{-4}$ |
| Penetration % | 78.3 | 0.18 | 0.18 | 5.35 |
| Efficiency % | 21.7 | > 99.82 | > 99.82 | 94.65 |
| Panel Resistance in. of $H_2O$ at 1 fpm | 0.33 | 0.32 | 0.33 | 0.18 |

* All panels tested at 1 fpm (1 cfm per sq. ft.) for 15 minutes.

** Fiberglas mat consists of FG-50 3/8 inch thick Fiberglas medium purchased from the Owens-Corning Fiberglas Co., Newark, Ohio. Downstream face and all other panels use 1106-B all glass media purchased from the Mine Safety Appliances Co. (Mfg. by Hurlbut Paper Co., So. Lee, Mass.).

TABLE 1

EFFICIENCY OF HARVARD DIFFUSION BOARD FOR PARTICULATE REMOVAL
(Uranine Aerosol - 0.07μ)*

| Size and Adsorbent | 1" Unfilled | ½" Unfilled | 1" Silvered Silica Gel 6-16 mesh | ½" Silvered Silica Gel 6-16 mesh | 1" Activated Carbon 12-30 mesh | ½" Activated Carbon 12-30 mesh | 1" Activated Carbon Fiberglas Layer Upstream | ½" Activated Carbon with Fiberglas Layer** Upstream |
|---|---|---|---|---|---|---|---|---|
| Upstream loading $mg/m^3$ | 8.08 | 7.75 | 8.00 | 7.59 | 5.11 | 6.93 | 8.42 | 8.98 |
| Downstream loading $mg/m^3$ | $0.064 \times 10^{-4}$ | $0.164 \times 10^{-4}$ | $0.128 \times 10^{-4}$ | $0.692 \times 10^{-4}$ | $0.320 \times 10^{-4}$ | $0.128 \times 10^{-4}$ | $0.471 \times 10^{-4}$ | $4.09 \times 10^{-4}$ |
| Penetration % | $0.79 \times 10^{-4}$ | $2.12 \times 10^{-4}$ | $1.60 \times 10^{-4}$ | $9.11 \times 10^{-4}$ | $6.27 \times 10^{-4}$ | $1.85 \times 10^{-4}$ | $5.59 \times 10^{-4}$ | $45.7 \times 10^{-4}$ |
| Efficiency % | 99.9999 | 99.9998 | 99.9999 | 99.9991 | 99.9994 | 99.9999 | 99.9994 | 99.996 |
| Panel Resistance in. of $H_2O$ at 1 fpm | 0.266 | 0.260 | 0.266 | 0.272 | 0.250 | 0.252 | 0.130 | 0.129 |
| Relative Humidity R.H. % | - | - | 15 | 13 | 15 | 22 | 22 | 23 |

* MD = 0.079μ ; σ = 1.78

** Fiberglas mat consists of FG 50 3/8 inch thick Fiberglas medium purchased from the Owens-Corning Fiberglas Co., Newark, Ohio. Downstream face and all other panels use 1106-B all glass media purchased from the Mine Safety Appliances Co. (Mfg. by Hurlbut Paper Co., So. Lee, Mass.)

## Table 3

## Confinement and Containment Methods

| | Type | Requirement | Examples |
|---|---|---|---|
| A. | Confinement | Maintain exhaust condition constantly through scrubber with or without filter with or without charcoal adsorbers. Prefiltered inlet and exhaust air in most cases. Building leaks inward but not able to withstand stored energy. Need fog sprays to lower temperature or to quench burning fuel slugs. | (a) Oak Ridge X-10 Air cooled pile<br>(b) Brookhaven Research Reactor BRR<br>(c) Production piles at Hanford and at Savannah River<br>(d) Oak Ridge Research Reactor ORR |
| B. | Containment | Maintain static pressure with specified leak pressure usually 0.1% Vol. per 24 hours at design pressure.<br>Use sprays to lower pressure. | (a) Pressurized water such as Shippingport Yankee<br>(b) Boiling water Such as Dresden Big Rock |
| C. | Containment plus Confinement | Combines B with A. Filter system is provided - cleanup leakage from primary vessel in event of accident. | Pressurized water. Such as Indian Point N.S. Savannah |
| D. | Containment plus pressure suppression | Small containment vessel which vents steam & stored energy to quench tank (Suppression pool). Final contained volume must percolate through water. Leakage requirements same as containment vessel. | Pressurized water such as PM-2A Ft. Greeley Alaska<br>Boiling water such as Humboldt Bay Bodega Bay |

Table 3 (Cont'd.)

| | Type | Requirement | Examples |
| --- | --- | --- | --- |
| E. | Containment plus valving | Similar to A except valves are provided to release stored energy. After accident and steam release-cleanup system becomes operative. | Pressurized water Such as NPR (Hanford) |
| F. | Double Containment | Similar to single containment except annular space between two containment vessels spaced several feet apart and which can be filled with porous media is continuously pumped to a negative pressure with respect to the ambient atmosphere. | Pressurized water Such as Los Angeles Malibu Beach |
| G. | Confinement with Diffusion Boards | Similar to containment except that all but noble fission gases are decontaminated and released to atmosphere without pressure rise. | Any type None yet installed |

Table 4

## Confinement Versus Containment Filter Requirements

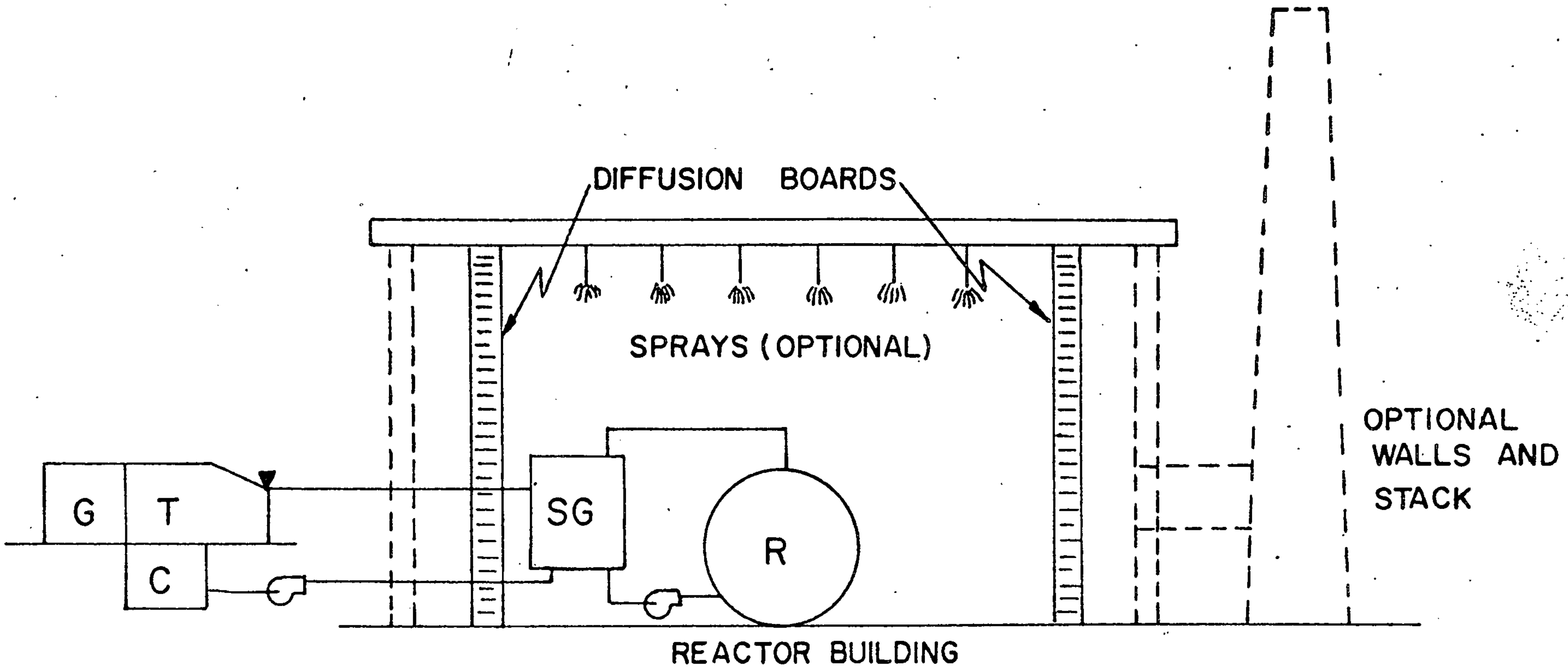
| 1. | Item | Confinement | Containment |
|---|---|---|---|
| 1. | Filter Use | Routine & Accident | Accident |
| 2. | Availability | Immediate | Requires actuation time (secs.) |
| 3. | Filter or Adsorber efficiency ($\eta$) | High - preferably $\eta$>99.99% (P = 0.01%) or DF = >$10^4$ | Nominal $\eta$ = 95 - 99% (P = 5-1%) DF = 20 to 100 |
| 4. | Filter capacity | Equal to system through put for needed pressure drop usually - 0.5 to 1.0" $H_2O$ | Based on desired recirculation rate and filter efficiency ≅ 1/20 vol/min. |
| 5. | Filter Resistance | Must not exceed exhauster capacity at final holding capacity. Usually 3-4" $H_2O$ | Same as confinement Can use higher pressure drop since capacity and power is less. |
| 6. | Building inlet filter | Necessary | Unnecessary |
| 7. | Prefilter | Desirable for long life | Depends upon entry location Usually desirable |
| 8. | Filter life | Should be 1-2 years and equal to holding capacity at time of anticipated accident loading. | Shelf condition >5 years Holding capacity = accident loading |
| 9. | Agglomeration and filter life and efficiency | Benefits slight | Great benefits on efficiency (overall) on release reduction |
| 10. | Resistance to steam and water droplets | Necessary | Necessary |
| 11. | Shock wave resistance or protection | Depends on location | Necessary |
| 12. | Ambient pressure | Unnecessary beyond 1 to 3 psi | Must work at 15 - 150 psi |

Table 4 (Cont'd.)

| Item | Confinement | Containment |
|---|---|---|
| 13. Thermal resistance | Low ($\angle$100°C) | High ( >200°C) |
| 14. Chemical resistance | Some ($O_3$, $NO_2$) but low due to dilution | Moderate depends on kind of reactor and release hydrolysis, etc. |
| 15. Flow or volume control | Variable, usually 2 speed | Fixed |
| 16. Filter aids from steam release and fog sprays | Small (rapidly diluted by inlet air) | Large Produces condensation growth and washout of small particles |
| 17. Effect on noble gases | None - Produces dilution to stack release only. | Retained within containment. Those that decay to solid daughters are removed by filter |
| 18. Effect on adsorption | Minimal - continuous desorption takes place. | Maximum Desorbed halogens are collected continuously |
| 19. Flexibility | High | Low |
| 20. Maintenance and recovery | Easy | Difficult |
| 21. Capital investment | Moderate | High |
| 22. Operating Cost | Moderate | Nil |

# CONFINEMENT AND CONTAINMENT METHODS

## G. DIFFUSION BOARD CONFINEMENT

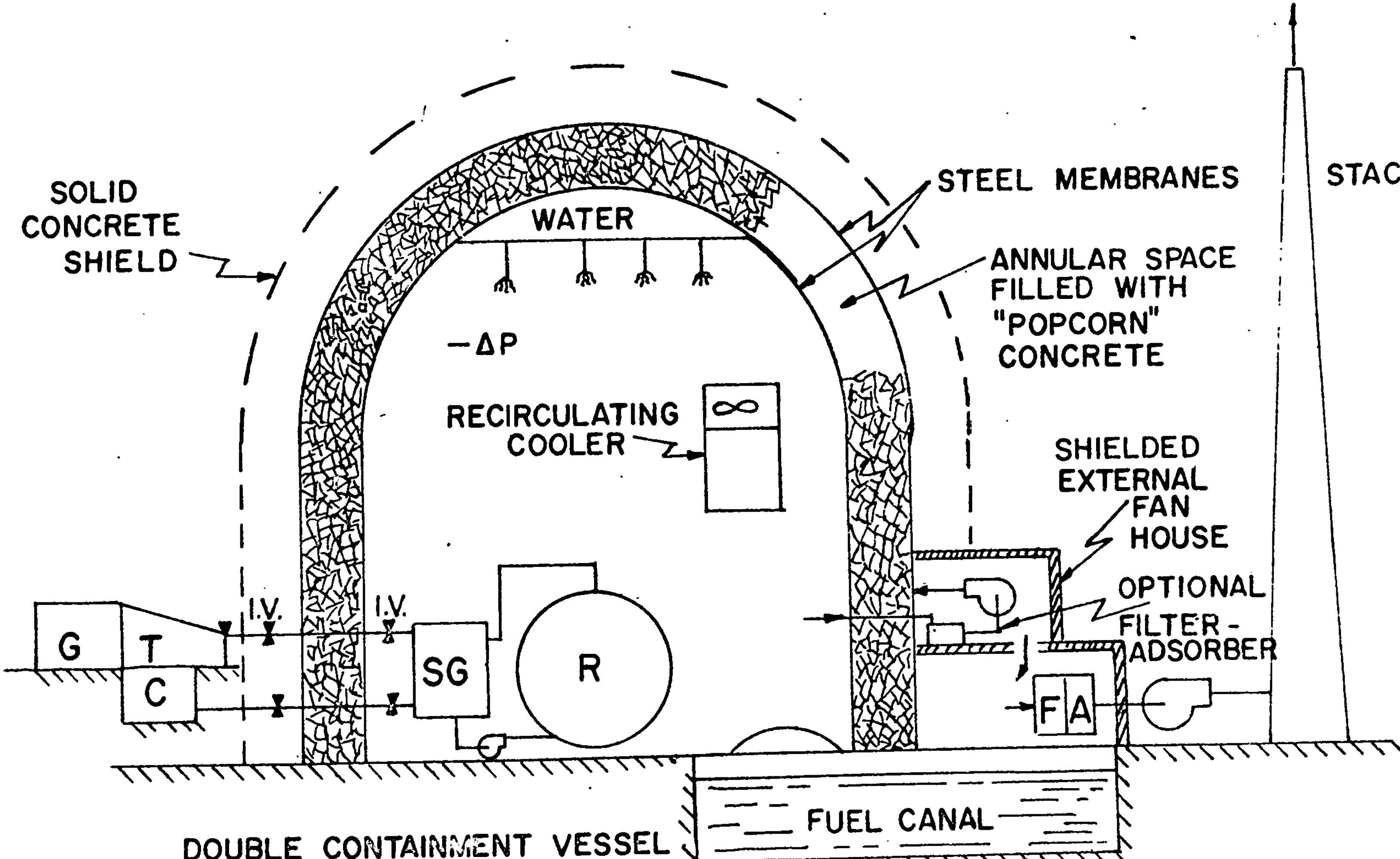



DIFFUSION MEMBRANE WALLS
POROUS TO GASES AND STEAM

SHOCK AND MOISTURE RESISTANT
HIGH EFFICIENCY HALOGEN AND
PARTICULATE FILTER-ADSORBER

## CONFINEMENT AND CONTAINMENT METHODS

### F. DOUBLE CONTAINMENT

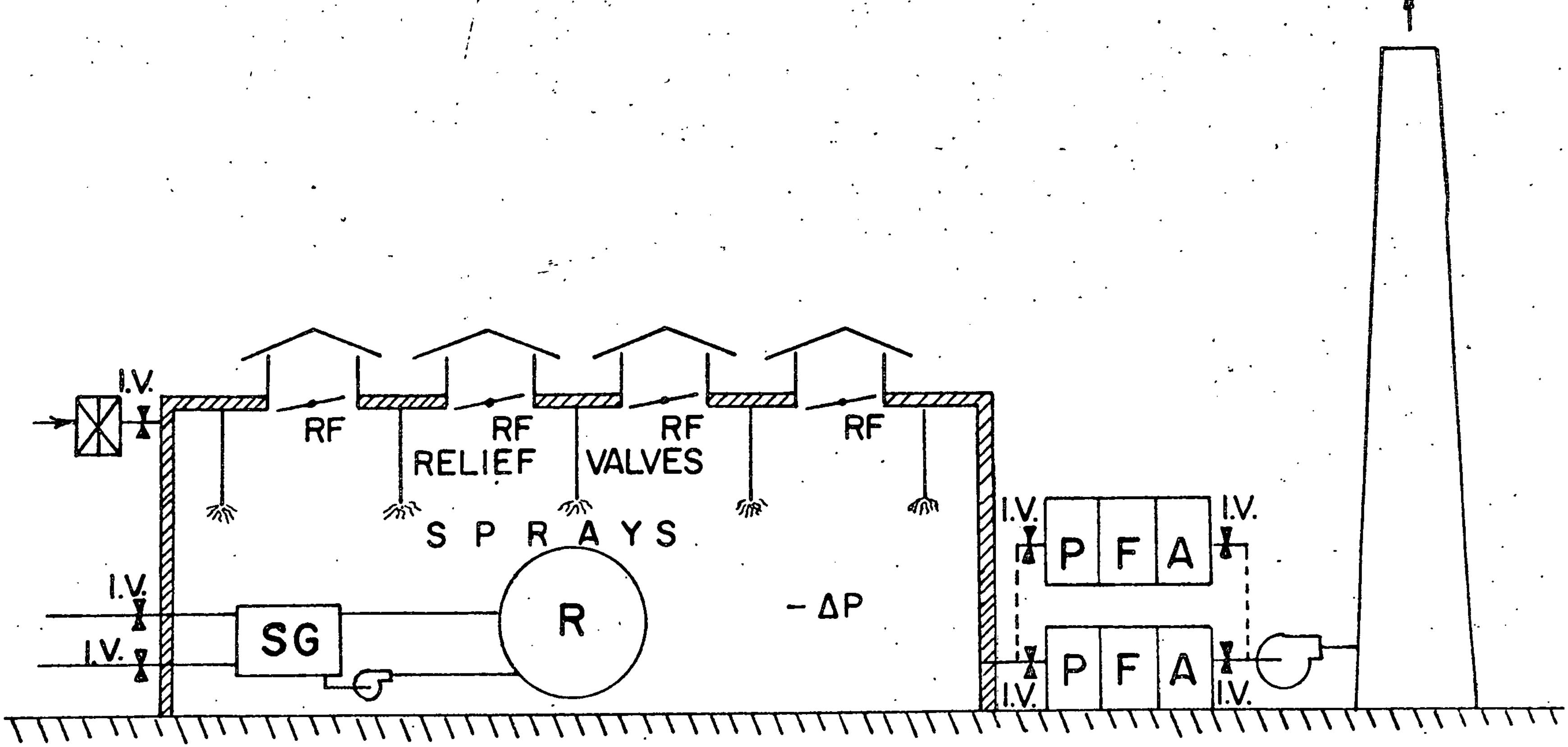



DOUBLE CONTAINMENT VESSEL

1. STEEL MEMBRANES WITH SUPPORTING "POPCORN" FOR POROUS LOAD BEARING WALL
2. INTERNAL PRESSURE TO MEET DESIGN VALUE
3. LEAKAGE EACH MEMBRANE – 0.1 % PER 24 HOURS

# CONFINEMENT AND CONTAINMENT METHODS

## E. CONTAINMENT WITH VALVING

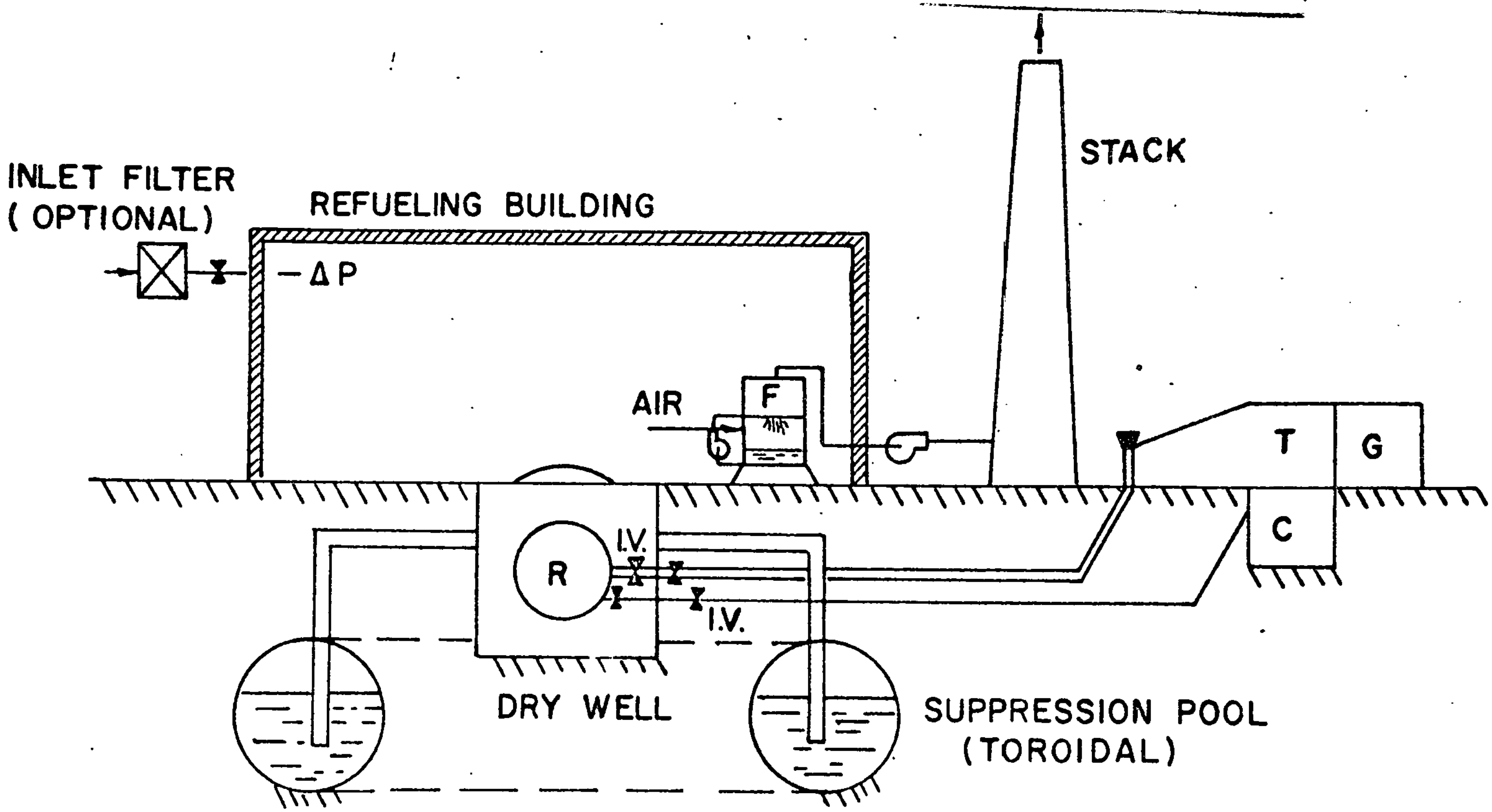



REACTOR BUILDING

1. REINFORCED CONCRETE
2. DYNAMIC PRESSURE 10-12" $H_2O$ -ΔP.
3. STATIC PRESSURE 4-5 PSI.

# CONFINEMENT AND CONTAINMENT METHODS

## D. CONTAINMENT PLUS PRESSURE SUPPRESSION




REACTOR = BWR

REFUELING BUILDING (MASONRY OR METAL)

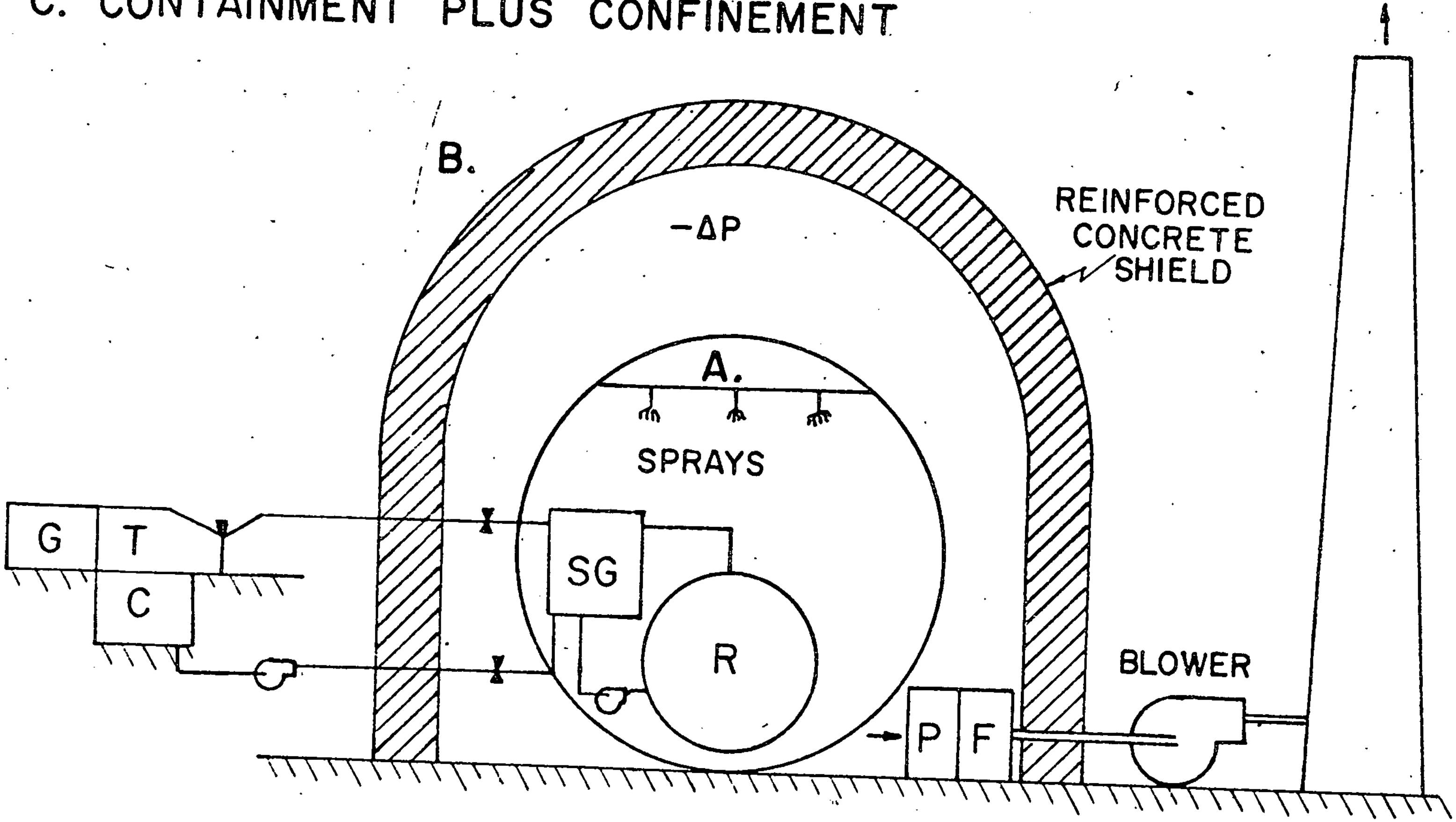
DYNAMIC PRESSURE 1.0" $H_2O$

STATIC PRESSURE 1-2 PSI

LEAKAGE - MINIMAL TO REDUCE SIZE OF SCRUBBER-FILTER UNIT

# CONFINEMENT AND CONTAINMENT METHODS

## C. CONTAINMENT PLUS CONFINEMENT




A. CONTAINMENT VESSEL

STEEL OR REINFORCED CONCRETE TO SAME SPECIFICATIONS AS CONTAINMENT ALONE

B. CONFINEMENT VESSEL

REINFORCED CONCRETE – STRENGTH PROVIDED BY SHIELDING

DESIGN MAINTAINS – 6" $H_2O$ ΔP

# CONFINEMENT AND CONTAINMENT METHODS

## B. CONTAINMENT

T= TURBINE

G= GENERATOR

C= CONDENSER

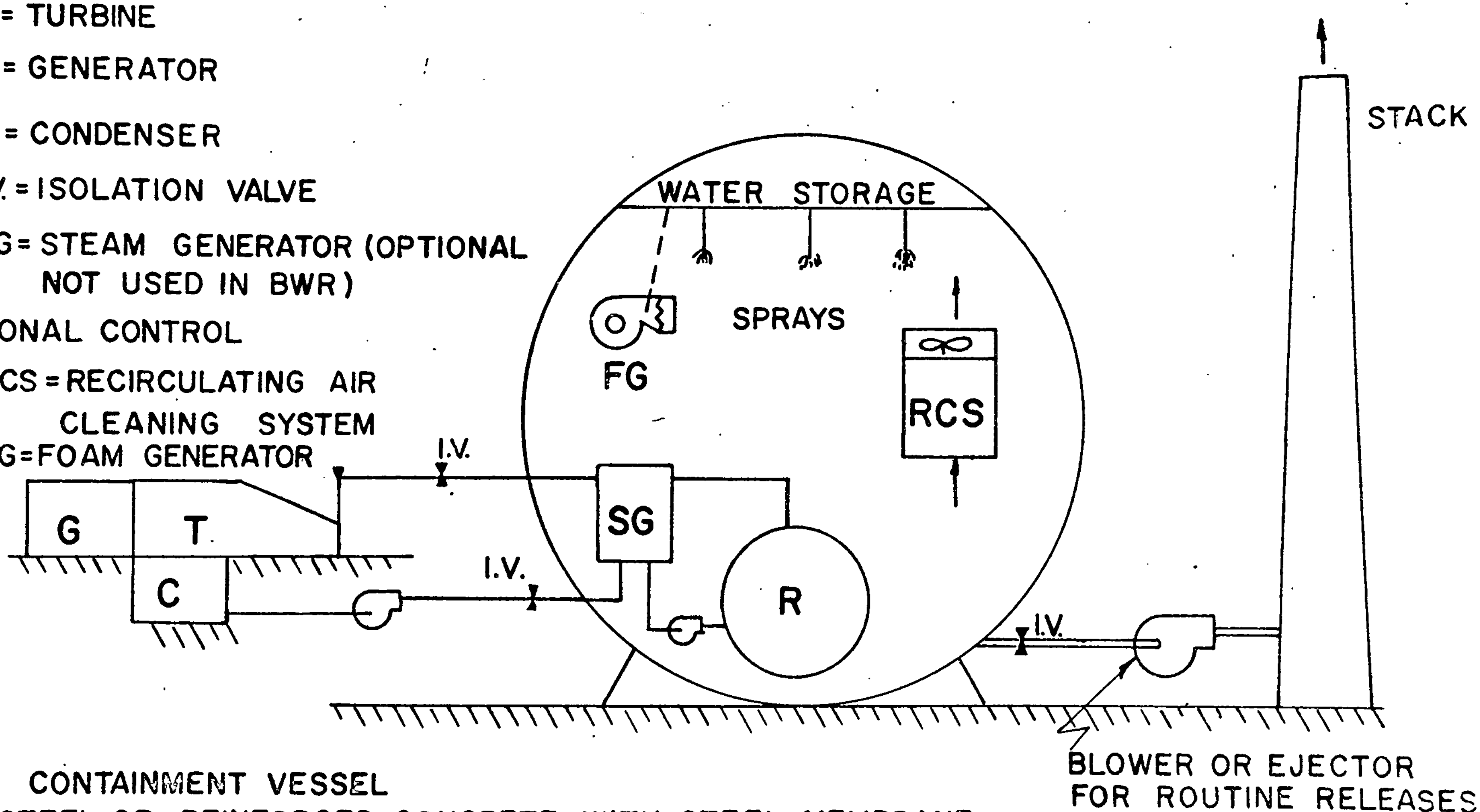
I.V. = ISOLATION VALVE

SG= STEAM GENERATOR (OPTIONAL NOT USED IN BWR)

OPTIONAL CONTROL

RCS = RECIRCULATING AIR CLEANING SYSTEM

FG=FOAM GENERATOR

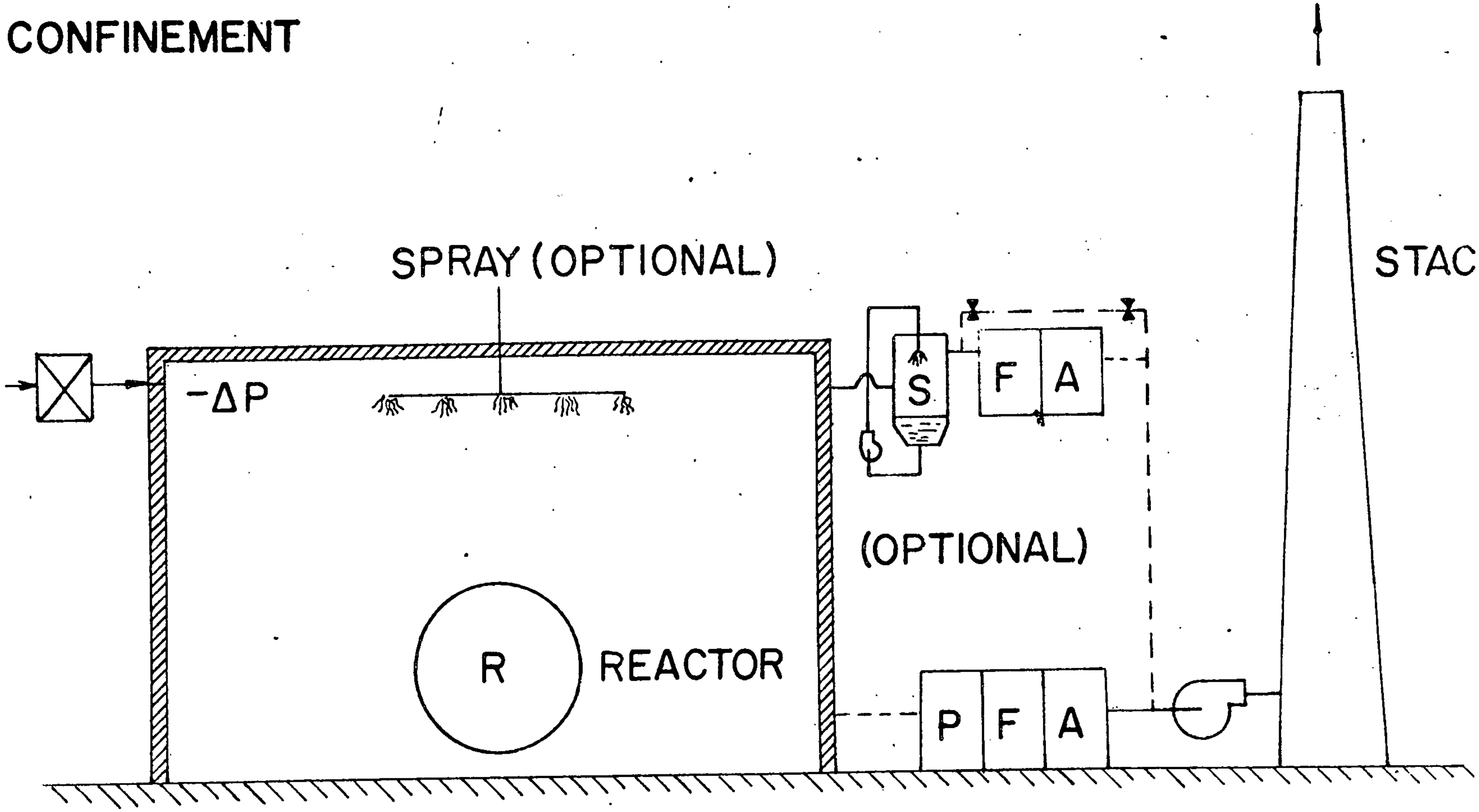



CONTAINMENT VESSEL

1. STEEL OR REINFORCED CONCRETE WITH STEEL MEMBRANE
2. STATIC PRESSURE EQUAL TO DESIGN RELEASE CONDITIONS
3. DYNAMIC LEAKAGE = 0.1% OF VOLUME PER DAY AT DESIGN PRESSURE. (LEAKAGE SPECIFIED MAY BE GREATER OR LESS)

# CONFINEMENT AND CONTAINMENT METHODS

## A. CONFINEMENT




REACTOR BUILDING

1. MASONRY OR METAL
2. DYNAMIC PRESSURE – 1" $H_2O$
3. STATIC PRESSURE $1\frac{1}{2}$ - 2 PSI

P = PREFILTER
F = FILTER
A = ADSORBER